Due: Oct 31, 2024

Energy: Science, Technology, and Society

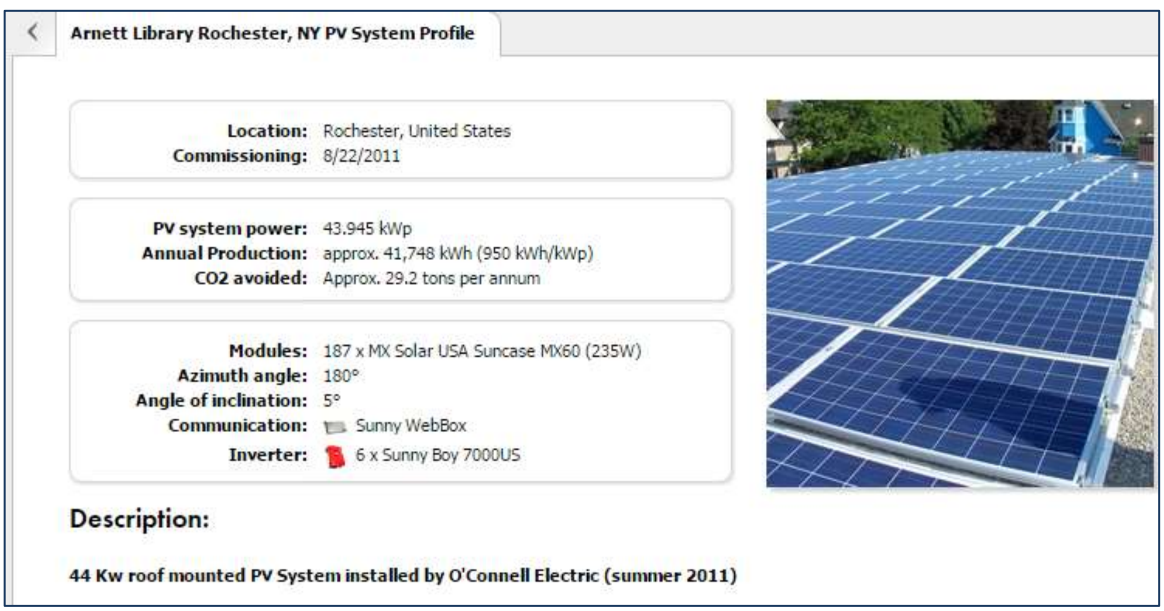
Project

Case Study of 2022 Solar Power Generation in Rochester

The main goal of the project is to evaluate and illustrate the utility of solar power generation in the NW New York area. Actual data for the performance of a medium-sized (residential) solar PV array will be gathered and analyzed in terms of seasonal and overall yearly efficiency (capacity factor CF), as well as in terms of the cost of delivered electricity and the avoided carbon emissions.

Description and Operation of the Arnett Array

In 2011, the City of Rochester had a solar PV array of 44 kW nominal power output installed on the rooftop of the Arnett branch of the Rochester Public Library. A PV cell is a semiconductor device that produces electricity when irradiated with Sun light.



https://www.sunnyportal.com/Templates/PublicPageOverview.aspx?page=f766fcda-84c3-4e9f-aecb-52f8ef9087ef&plant=405ee5cd-1beb-4f75-b59f-35bcbecfcb94&splang=en-US

The specifications of the array are listed in the table and the provided data sheet. They are also posted on the web, e.g., at the URL given above. The cost of the PV panels, including installation, was $3.15/W in 2011. (The total system nominal prices have not changed very much in recent years.) Estimated lifetime of the array is of the order of 20 years. Cleaning and maintenance for the PV array are estimated at a low $350/mo. Operational costs include $35.00/mo. for the rental of a smart (two-way) switch connection to the electrical grid run by the utility RG&E. The nominal Arnett array power has been customized such that the array can serve the entire operational power requirements by the library, averaging at 18 kW during public hours. During off hours, residual power requirements remain, but decrease to 5 kW. Surplus power produced by the array can be fed back into the electrical grid and is credited as "reimbursement" at the regular utility wholesale price.

Project Tasks

1. Obtain solar isolation data for Rochester **for the year of 2022** (the most recent data). Explore and then use the National Solar Radiation Database (NSRDB) to access data of hourly and half-hourly values of most common measurements of solar radiation: global horizontal, direct normal, and diffuse horizontal irradiance, in addition to meteorological data. The "Download Wizard" at the link https://maps.nrel.gov/nsrdb-viewer/?aL=x8CI3i%255Bv%255D%3Dt%26Jea8x6%255Bv%255D%3Dt%26Jea8x6%255Bd%255D%3D1%26VRLt_G%255Bv%255D%3Dt%26VRLt_G%255Bd%255D%3D3%26VRLt_G%255Br%255D%3Dt%26mcQtmw%255Bv%255D%3Dt%26mcQtmw%255Bd%255D%3D2%26mcQtmw%255Br%255D%3Dt&bL=clight&cE=0&lR=0&mC=43.1430821780996%2C-76.67633056640625&zL=8
will direct you to a world map. Focus on the US and the Rochester area.

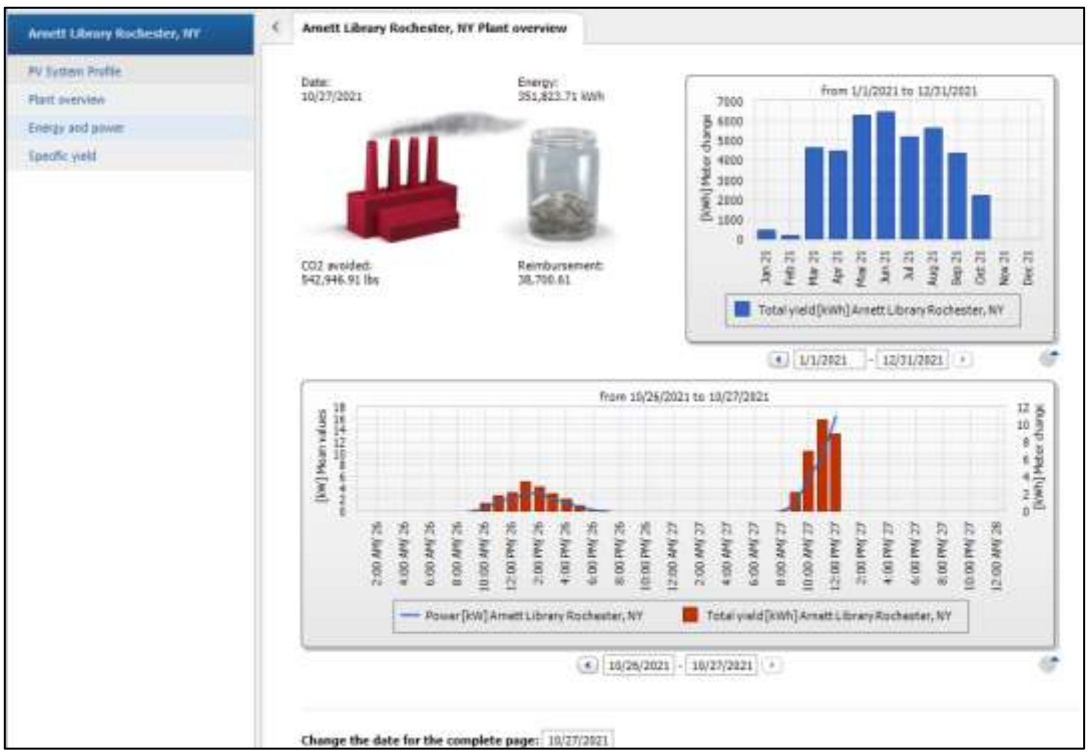
Clear sky DHI	Watt/m^2	Solar radiation on a horizontal surface received from the sky excluding the solar disk, clear sky
Clear sky DNI	Watt/m^2	Solar radiation obtained in normal incidence, i.e., from the direction of the sun, clear sky condition
Clear sky GHI	Watt/m^2	Solar radiation on a horizontal surface received generally from the sky, clear sky condition
Cloud Type	Unitless	Obtained from PATMOS-X
Dew Point	Degree C	Calculated from specific humidity
DHI	Watt/m^2	Solar radiation on a horizontal surface received from the sky excluding the solar disk.
DNI	Watt/m^2	Solar radiation obtained from the direction of the sun.
GHI	Watt/m^2	Solar radiation on a horizontal surface received from the sky.

A menu item "**Direct Normal Irradiance**" provides current and historical data relevant for the Arnett location.

Consider the types of radiation power listed in the table above and briefly discuss their expected qualitative effect on the Arnett solar array for the month of August 2022.

2. Analyze the 2022 data and calculate the average daily percentage of the *incident solar radiation* power received by Rochester. (For historic comparison, in the recent past, the Rochester area received on average 51% of the incident radiation, according to NOAA.)

3. Access and retrieve the published 2022 data on *electrical power generated* by the Arnett solar array. Sample data are shown in the screen shot below about the electric power generated by this array. Detailed access to these data have been posted and are accessible in graphical form at the URL https://www.sunnyportal.com/Templates/PublicPageOverview.aspx?page=f766fcda-84c3-4e9f-aecb-52f8ef9087ef&plant=405ee5cd-1beb-4f75-b59f-35bcbecfcb94&splang=en-US



4. Describe qualitatively and quantitatively the observed daily, monthly and seasonal patterns of power generation by the Arnett solar array. *For example*, compare the daily power output in one week of March 2022 to a) one week in July and b) one week in October of 2022. Calculate the corresponding experimental means and standard deviations for the power outputs. Generate plots for illustrating your discussion of observations.

5. Find out how many "dark days" the Arnett solar array experienced in 2022, where the power output was below 10% of the nominal ("nameplate") power during the hours of operation of the library? How many "dark periods" were there in 2022 having more than 1 dark day in a row? How long was the longest dark period?

6. Use the actual mean solar insolation on the Rochester area and the mean power output of the array to deduce the mean conversion efficiency/capacity factor CF of the array. (Explain why this method does not provide the most precise value for CF.)

7. Estimate the direct cost per kWh delivered by the Arnett Array in 2022. Prorate the acquisition and installation costs over the expected 20 years of operation.

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8. Calculate the amount of CO_2 avoided by operating the array, as compared to the same power produced by a natural gas power plant with 42% efficiency.
(Useful info: Nat gas contains an energy of 127 kWh per Mcf (1,000 cubic feet) and burns 8,039 Btu/kWh of electricity, produces 50.3kg CO_2/GJ.)

9. Summarize the main findings of your study and provide a data based argument for the prospects of solar power in Western NY as replacement for conventional power sources.

10. Write up the study as a formal research paper using the provided template (or similar) with a logical setup of sections (Title, Bylines, Abstract, Introduction,..., Summary and Conclusions) and appropriate discussions of findings.

Additional tasks for Chem 486 Credits:

11. Discuss and rate technical specifics of the PV cells used in the Arnett Array (attached data sheet) relative to more modern cells advertised on the Web.

12. Assume an owner of a solar array in the Rochester area with a similar nominal (peak) power as the Arnett array who has a net daily electrical power need of 30 kW during normal business hours. What supplemental (dispatchable) power (e-grid supply or stored battery) does it require to guarantee near-100% service?

Note that base-power stations (gas, coal, nuclear stations) must idle at some non-zero power level, to be able to ramp up quickly. Assume as backup a natural gas power station idling at 15% of maximum power.

13. Scale the results obtained in the study of the Arnett array in order to design and cost operation of a much larger solar "farm" in NW NY capable of producing an average 100 MW of electrical power (1/8 of the power generated by the local Ginna nuclear plant). Base your scaling on the actual 2022 solar data for NW NY.

14. How much land area (in ha) would such a solar farm occupy? Assume that app. 90% of the required area can actually be covered by (horizontal) solar panel and support structure.

MX Solar USA MX60-230 (230W) Solar Panel

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This page contains information about the MX Solar USA MX60-230 (230W) solar panel. To compare this to other PV modules, click here.

- **Manufacturer Data Sheet**
- **Installation Manual**

DC Electrical Characteristics

- STC Power Rating 230W
- PTC Power Rating 205W [1]
- STC Power per unit of area 12.8W/ft^2 (137.5W/m^2)
- Peak Efficiency 13.75%
- Power Tolerances 0%/+2%
- Number of Cells 60
- Nominal Voltage not applicable
- Imp 7.84A
- Vmp 29.3V
- Isc 8.36A
- Voc 36.8V
- NOCT 44.7°C
- Temp. Coefficient of Power -0.54%/K
- Temp. Coefficient of Voltage -0.138V/K
- Series Fuse Rating 15A
- Maximum System Voltage 600V

Mechanical Characteristics

- Type Polycrystalline Silicon
- Output Terminal Type Multicontact Connector Type 4
- Frame Color Clear
- Backsheet Color data not available
- Length 65.6in (1,665mm)
- Width 39.6in (1,005mm)
- Depth 1.7in (43mm)
- Weight 48.5lb (22kg)
- Installation Method Rack-Mounted

Warranty and Certifications

- 80% Power Output Warranty Period 25yrs
- 90% Power Output Warranty Period 10yrs
- Workmanship Warranty Period 10yrs
- UL Fire Classification data not available
- Compliances UL 1703
- CSI Listed Yes (California Solar Initiative (CSI) list of Eligible Modules)